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IAN BUTTERWORTH CBE
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Elected FRS 1981

BY PETER DORNAN* FRS

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Ian Butterworth was a major force in European particle physics from the start of the subject in the late fifties until leaving his post as the European Organization for Nuclear Research (CERN) research director in 1986 to become principal of Queen Mary College. Following his PhD at Manchester, he moved to Imperial College, where later he was head of both the high energy group and the physics department. His early research was dominated by bubble chamber analyses searching for resonant hadronic states, crucial for the establishment of the quark model. Investigating these resonances, using mass spectra and partial wave analyses, was his speciality. He had vision. He was one of the first to recognize the value of IT advances, the importance of networking and the vast potential of the Web.

In 1990, at the age of 60, he had a stroke but less than a year later he was again active. His main interests became the effective use of the Web for electronic publishing and the advancement of a coherent European network strategy for education and research. Much of this was under the auspices of the Academia Europaea, of which he was vice president from 1997 to 2003. In his later years he retained a deep interest in European culture and gastronomy and continued to enjoy travelling around Europe. Ian was a special person, warm-hearted, lively and excellent company.

EARLY YEARS

Ian Butterworth was born on 3 December 1930 in Tottington, East Lancashire, and brought up in a small village between Bolton and Burnley. His first school was a village school which remains active today, St Mary’s Church of England school in Hawkshaw, about one and

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half miles from home. At 11, during the war period, he moved to the main Bolton school, the Bolton Municipal Secondary School, which became Bolton County Grammar School following the 1944 Education Act, and Withins Comprehensive in 1988.

At secondary school, he concentrated on science for his Higher Certificate and, with an excellent rating for scholarship-level physics, his future path began. In 1948 Manchester physics was at a high point: Patrick Blackett (FRS 1933) having just obtained the Nobel Prize for his work on cosmic rays. It was therefore natural that Ian would move to his local university in Manchester. During his undergraduate time, his delight in the complexities of physics grew and in 1951 he obtained his first degree and the Samuel Bright Research Award for the top physics student.

**EARLY RESEARCH**

As top physics student, he could choose a research group and so enthusiastically joined Blackett’s cosmic ray group with a grant from the Department of Science and Industrial Research. Thus began his association with the world of elementary particles. His supervisor was H. J. J. Braddick, who had worked closely with Blackett during the war and was an expert on experimental technique, in particular the use and development of the cloud chamber, the standard technique at that time for investigating cosmic rays. Ian’s doctoral period was devoted to advancing this technique and he developed a new photometric device to measure track ionization density which could be applied to tracks with unresolved droplets. This was a significant step forward as the ionization reveals the particle velocity, which, with the momentum from the track curvature in a magnetic field, yields the particle mass and hence its nature. For his thesis, he employed this technique to measure the mass of tracks from $K^-$ meson decays, the strange particles which had been discovered during the late 1940s by Clifford Butler (FRS 1961) and George Rochester (FRS 1958), also working at Manchester.

During this period, Ian made his first journey overseas to an international cosmic ray conference in the Alps. It started his subsequent delight in travelling, absorbing the culture of different countries and the interaction with other physicists. Shortly afterwards, Ian was to give his first talk at a conference on developments in cloud chamber techniques and to produce his first publication (1)*.

Following his PhD in 1954 he took a post as a scientific officer at the UK Atomic Energy Research Establishment (AERE) Harwell as an alternative to National Service. There, he joined a group nominally in the nuclear physics division, but actually conducting research on materials for the production of a cold neutron source (2). He also spent a few months with a theory group working on a damped-phonon theory of neutron scattering. However, these experiences of theoretical and nuclear research reinforced his view that he would take the experimental path and move back to elementary particles.

A different feature of his time at AERE, which did have a long-term impact, was an interest in the performing arts. He took part in amateur dramatics with the AERE and Abingdon dramatic groups and set up the AERE Film Society. When he left AERE for London, this activity continued with the Kensington drama group, with whom, in 1962, he played his greatest part, that of Aegisthus in Pierre Rouve’s *Electra*. This interest in stage and screen

* Numbers in this form refer to the bibliography at the end of the text.
The bubble chamber era

In the mid fifties, the particle picture was very different from today. Atoms were known to consist of a nucleus of protons and neutrons, surrounded by a cloud of electrons. In addition, some unstable particles had been discovered with a sufficiently long lifetime that they could leave tracks in a cloud chamber. Those known were the muon, a mysterious particle which just behaved like a heavy electron, the strongly interacting pi mesons (pions) and the strange particles, previously discovered at Manchester by Butler and Rochester which also interacted strongly. The known strange particles consisted of charged and neutral K mesons (kaons), a neutral lambda baryon and charged and neutral sigma baryons. Baryons feature a proton or neutron when they decay, the mesons do not, and so the first classification of states was into mesonic and baryonic classes. The kaons, charged pions, the muon, the lambda and charged sigmas all decayed weakly with lifetimes ranging from $10^{-6}$ s to $10^{-12}$ s, sufficiently long to leave a track in a cloud chamber.

A revolution occurred during the late fifties and early sixties as a whole new set of states started to be discovered. They were created in particle collisions, but decayed via the strong interaction in around $10^{-24}$ s, too quickly to leave tracks and so their existence had to be inferred from their observed decay products. They were termed resonances and their classification would play a major role in the later emergence of the quark picture. Discovering, classifying and understanding these resonances would now dominate the next years of Ian’s career as he became a world expert.

Two advances during the fifties were crucial for these discoveries. One was the commissioning of synchrotrons which could deliver energetic beams of protons, pions and kaons, and the other was the invention of the hydrogen bubble chamber. The bubble chamber would become the basic tool for investigating the resonances as the tracks of the charged particles emerging from an interaction could be photographed and their momentum determined by curvature in a magnetic field. The bubble chamber was the natural extension of the cloud chamber, but much more effective owing to the greater mass of the liquid target and the ability to synchronize its expansion with the synchrotron beam. Ian’s particle physics work would now concentrate on analysis of bubble chamber data.

Imperial College, 1958–1964

Donald Glaser had invented the bubble chamber in 1952 and Clifford Butler was quick to appreciate its potential. In 1953 Blackett and Butler moved from Manchester to Imperial College, London: Blackett to become head of the physics department and Butler to establish the High Energy Nuclear Physics group with a bubble chamber sub-group. In 1958 Ian was awarded a lectureship at Imperial to build up the bubble chamber activity, but things did not start well. His first project was to help Norman Barford with what was to become an overly ambitious project for a university group. This was to build a 16” bubble chamber to be used at the Saturne synchrotron at Saclay, France. The project was a disaster. There were numerous engineering faults, making it very late, and when, in 1960, it was finally moved to France, it leaked and had to be abandoned. It was a salutary experience he never forgot; it left him with
an appreciation of the importance of quality engineering for the large projects which would lie ahead.

From that time, he concentrated on analysing bubble chamber film and the emphasis moved to a programme of building scanning tables and measuring machines to handle the large numbers of photographs being produced at the accelerator laboratories. This was labour intensive and teams of scanner/measurers were employed covering 24 h each working day. Large collaborations formed to handle the task of analysing the photographs and in 1962 Ian led the Imperial group into an Anglo–German collaboration involving groups from Aachen, Birmingham, Bonn, Hamburg and MPI Munich using the Saclay 81 cm chamber to take data of interactions produced by beams of 4 GeV/c positive and negative pions generated at the CERN Proton Synchrotron (PS). The aim was to verify earlier US claims for resonant states and search for new ones. The first significant result was the verification of the existence of the f° resonance, a π⁺π⁻ state (3), and later evidence was produced for the a1 and a2 resonant states (4).

Nuclear and particle physics activities in the USA were considerably ahead of European ones at this time and virtually all the early work on the discovery and classification of the resonances took place there. In the USA there were two major laboratories in this area. On the east coast it was the Brookhaven National Laboratory and on the west coast, the Lawrence Radiation Laboratory at Berkeley. At Brookhaven, the 3 GeV Cosmotron started operation in 1953, but this was soon upstaged in 1954 by the Berkeley 6 GeV Bevatron. These remained the dominant machines until the CERN PS, operating at the significantly higher energy of 28 GeV, would come into operation in 1959, but this was soon overtaken by the 33 GeV Brookhaven Alternating Gradient Synchrotron (AGS) in 1960. Hydrogen bubble chamber development followed a similar pattern, with the important parameter being size. Around 1958 the Shutt 20″ chamber was constructed at Brookhaven, but the real workhorse during this period was the Alvarez 72″ chamber at the Bevatron, until 1963 when the Brookhaven 80″ chamber started operations at the AGS.

Europe eventually joined this activity in the early sixties using beams from the CERN PS, but the Europeans were playing catch-up and the expertise for bubble chamber analysis was primarily in the US. As a result, many aspiring European particle physicists moved either temporarily or permanently to the US to continue their research; Ian was one of these.

Research physicist, Lawrence Radiation Laboratory, Berkeley, California, 1964–1965

Appreciating the gulf between particle physics activities in Europe and the USA, in 1964 Ian took a year’s leave of absence from Imperial College to take up a physicist position at Berkeley, then considered the prime location for the investigation of the resonant states.

Before leaving, however, there was another significant milestone. While at AERE, he had often visited Imperial and met Mary Gough, a technician working in Butler’s group. The acquaintance was renewed when he moved to London, and they were married on 9 May 1964, and so, essentially, they started married life in California.

Berkeley was a stimulating place to be in those days. Luis Alvarez generated a culture of excitement; there was encouragement for new ideas, lively discussion and a can-do approach. Ian joined the bubble chamber sub-group led by Gerson Goldhaber analysing film produced at Brookhaven involving π and K beams from the AGS, into the 80″ chamber filled with deuterium. This enabled interactions on both neutrons and protons to be compared. His specific investigations were on strange mesonic resonances and directed towards an earlier
disputed claim for a K\(^*\)(1320) resonance. This was an item of controversy as it concerned the existence of a group of resonant states referred to as the 1\(^+\) octet for which the K\(^*\)(1320) would be the strange member. The Berkeley team’s analysis produced supporting evidence for this state (5). It was an important step supporting the quark model, as the members of this group would be the first resonant states for which the component quarks had a non-zero orbital angular momentum.

Berkeley was a hotbed of innovation and many new ideas were conceived to make bubble chamber analysis more efficient. The aim was to maximize the number of interactions photographed in a given time and minimize the time taken to scan the photographs and measure the tracks. One approach was to develop the first rapid cycling chamber, the Berkeley 25′′ chamber, which was able to take two pictures per Bevatron cycle. This improved the efficient use of the synchrotron, but put an extra load on the labour required for measuring and so it incorporated a second innovation, special marks on the film to guide a computer-controlled film measuring device then under development, the flying spot digitizer. Automation was in its infancy in the sixties, so this was a highly speculative project, but Ian was impressed and he realized the enormous future potential which would be provided by computing and automation.

Ian loved the life at Berkeley and both he and Mary took California to their hearts, so it became a difficult decision at the end of the year whether to stay in California or return to London. Ultimately the decision was to return, certainly helped by the promise from Butler of a senior lectureship.

Imperial College, 1965–1968

In 1965 Ian returned to Imperial with enthusiasm to implement some of the forward ideas he had found so compelling at Berkeley. The first was to ensure that the group had its own high quality computing, and in 1966 the group took delivery of a DEC PDP6 computer. This was ahead of its time: it did not use cards like the large machines from IBM, but a keyboard and screen with data stored on DEC tapes. It gave the group a major advantage. The main justification for the PDP6, however, was to control one of the first automatic measuring machines in the UK. This was the Hough–Powell Device (HPD), designed jointly by Paul Hough and Brian Powell. While the hardware of the HPD was made in industry, the control and pattern recognition software had now to be produced by the Imperial group.

As a result of his time at Berkeley, Ian was now a world expert on the resonant states and there were requests for reviews at major particle physics conferences and articles for the review journals. His first major review talk on meson resonances (6) was at the Heidelberg International Conference on Elementary Particles, soon to be followed by a review article for the Annual Review of Nuclear Sciences (7). However, there was also an even more significant event, Mary gave birth to their daughter, Jody, who would become a great help and support during his later years.

Meson resonances were invariably found by examining the structure, technically the invariant mass, of some of the particles produced in a multibody final state resulting from a proton–proton or meson–proton collision. This was termed ‘resonances found in production’. The first baryon resonances were also discovered in this way, but a much more effective way was to conduct a partial wave analysis on the overall final state following a meson–baryon collision. For this, the energy of the collision was varied and the angular production of the final states Fourier analysed to yield quantum numbers of any possible intermediate state.
produced. This was referred to as ‘resonances found in formation’. It was Ian’s next major direction. In 1967 the Saclay 80 cm bubble chamber was moved to the Nimrod accelerator at the Rutherford High Energy Laboratory (RHEL), now the Rutherford Appleton Laboratory, and a series of exposures took place with an incident $K^-$ beam in order to investigate strange baryon resonances. The first data were taken with deuterium in the chamber at two incident $K^-$ momenta, 1.45 GeV/$c$ and 1.65 GeV/$c$, and analysed by groups from Birmingham, Edinburgh and Glasgow as well as Imperial. An advantage of deuterium was that the internal energy of the nucleons in the deuterium extended the range of centre of mass energies, which could be investigated from 1.85 to 2.15 GeV. This enabled the team to confirm the spin-parity of the $\Sigma(1915)$ and $\Sigma(2030)$ states and also question the existence of others (8).

**Rutherford High Energy Laboratory, 1968–1971**

Ian’s reputation in the UK was now high and in 1968 he was asked to take over as head of the bubble chamber group at RHEL while also maintaining a position at Imperial College. In the same year, he was appointed to his first national committee, the Bubble Chamber Film Analysis Panel of the Science Research Council’s Nuclear Physics Board. Committees would now play an increasingly important part in his life.

Claims of new resonant states were frequent and many were false, so it was imperative that all claims were verified. To continue the investigation of strange baryon resonances Ian formed a collaboration with three French groups to expose the Saclay 80 cm chamber, this time filled with hydrogen, to $K^-$ beams from Nimrod at 13 beam momenta from $1.263 \text{ GeV/c}$ to $1.843 \text{ GeV/c}$. This allowed partial wave analyses to be conducted for a number of strange baryon resonances in the 1915 to 2168 MeV mass range which could be formed in the $K^-p$ collision but which could decay to other final states (9, 10, 12, 13).

Formation experiments were now clearly seen as the most powerful tool in the baryon area and this stimulated a new initiative from Ian’s RHEL group and the Liverpool bubble chamber group to extend the procedure to heavy mesonic states. In a $\pi^-p$ missing mass experiment at CERN, claims had been made for three new resonant mesonic states, labelled S, T and U, found in production. The proposal from the Liverpool–RHEL groups was to investigate the T state by means of a formation experiment using the CERN 2 m bubble chamber exposed to an antiproton beam. As with the baryon resonances, the incident beam energy was adjusted so that the centre of mass was close to the claimed mass of this T state. No evidence was found (11). Subsequently, other experiments also dismissed the claims.

However, film handling remained a difficulty. Finding the interactions and then measuring them was slow and required a substantial staff and consequently, building on his experience at Berkeley, Ian pursued the goal of automatic measurement. Progress on this front was not easy as computing power was limited, but ultimately a successful hybrid system evolved in which film would be scanned manually to find the frames with interactions and then provide rough measurements to assist an automatic measuring device to make accurate digitizations for analysis. The system proved very successful and became the major technique used for the remaining life of the bubble chamber.

Early in 1971 Ian enjoyed a short period back in California at Riverside, joining two of his old colleagues from Berkeley, Anne Kernan and Ben Shen. With his strange baryon expertise, the group produced a publication verifying a prediction based on a topical theory at that time, quark–graph duality (14).

However, particle physics processes are stochastic and some, including many important ones, occur only rarely, which posed the next difficulty for the bubble chamber technique.
In October 1971 Ian returned full time to Imperial College to take over as head of the High Energy group following Clifford Butler’s departure. Investigation of the properties of strange baryon resonant states continued with an Imperial–RHEL team and a new series of K⁻p experiments at lower incident energy in the 2 m bubble chamber at CERN. Over the next years, the data from these experiments were combined with earlier higher energy data for definitive partial wave analyses for a number of negative strangeness baryon systems in the 1710 to 2170 MeV mass range (16, 18, 19).

A departure from these investigations was an Anglo–European collaboration examining 12 GeV/c antiproton–proton interactions in one of the first experiments in the world’s largest bubble chamber: the Big European Bubble Chamber (BEBC) at CERN. It was an exploratory experiment examining many final states for evidence of new resonances in production and there was actually hope that a new strange one had been found decaying to Kπππ (17).

Previously many of Ian’s experiments had used the formation process to disprove the existence of resonant states found in production, and now he was to undergo the same disappointment; later experiments showed that the effect observed had just been a fluctuation.

Bubble chamber activity by his group broadened with numerous experiments. As well as continuing the classification of the resonant states, the data were used for other measurements. A significant one was a definitive measurement of the lifetime of the lambda baryon where previous experiments had produced conflicting results (15).

Additional responsibilities at College meant less time for day-to-day analysis and his efforts were now increasingly directed towards advancing the use of technology to improve and speed the measurement process. This would now become a driving force.

Semi-automatic measurement of bubble chamber photographs had proved a major advance, but there was still a problem. As theories of the mechanisms of particle interactions developed, the need for increasingly precise measurements of increasingly rare phenomena became significant. These required the detail available from the bubble chamber, but greater statistics than were conventionally possible. When Ian had been at Berkeley, the first rapid cycling chamber had been constructed, an approach subsequently picked up by Joe Ballam’s group at the Stanford Linear Accelerator Center (SLAC). On one of his visits to the US, Ian met Ballam and together they initiated the idea of the Imperial group taking part in an experiment with the 40’’ SLAC Fast Cycling Chamber. Ian was joined in this experiment by the author and they proposed exposures of the chamber to π⁺ and K⁻ beams to test exchange degeneracy, a critical prediction of Regge theory. The critical innovation was to have electronic detectors around the chamber to identify interesting events during the 2 ms bubble growth time and, only if found, to trigger a decision to take a photograph. As a result, the effective data-taking rate was not limited by the film movement. The Imperial group provided this trigger and became the first group from outside the US to conduct an experiment at SLAC. Other experiments followed and the SLAC Hybrid Facility programme became a major part of the group’s activities until 1980.

Despite the improvements in the bubble chamber technique, its place as the detector of choice was to be overtaken during the seventies by the rise of colliding beam experiments. These had started in the late sixties with very low energy e–e colliders, but remained a niche area until 1971, when CERN demonstrated the feasibility of a high energy proton–proton collider with the successful commissioning of the Intersecting Storage Rings (ISR). This employed two counter-rotating proton beams and could reach centre of mass energies up to
60 GeV, much greater than was possible with a stationary target. However, it took time to realize the most effective way to construct an experiment at a colliding beam facility, until the numerous successes of the Mark I experiment at the SPEAR electron–positron collider at SLAC. Mark I employed a solenoidal detector which enabled essentially all products of the collisions to be measured, producing results which had hitherto been the domain of the bubble chamber. At SPEAR during the seventies a fourth quark, the charm quark, and a third charged lepton, the tau, were discovered. It was clear that colliding beam experiments with solenoidal detectors could produce the pictorial results for which bubble chambers had been renowned, but at a much greater rate and at much higher energies.

Thus by 1980 the bubble chamber era was effectively over except in some specialist areas. One was neutrino physics, and this was the direction Ian next followed. It was before the days of neutrino oscillation, and the prime aim was to use neutrinos to probe the structure of the proton by deep inelastic scattering as they were unaffected by either the strong or electromagnetic forces. This was complementary to the use of the electromagnetically interacting electrons which had earlier given major insights into nucleon structure at SLAC. Neutrinos interact very rarely, but despite this a useful interaction rate can be achieved in a bubble chamber as long as it is big enough, contains a dense liquid and is exposed to a high flux neutrino beam. The commissioning of the 400 GeV Super Proton Synchrotron (SPS) in 1976 enabled CERN to generate intense high energy neutrino beams, and so, in 1977, BEBC was filled with a neon–hydrogen heavy liquid and moved to a neutrino beam from the SPS. A collaboration was formed with groups from Aachen, Bonn, CERN, Oxford and Saclay to measure the poorly known neutrino interaction rates and the nucleon fragmentation functions (20, 21, 23). It became one of the leading experiments of its day and continued into the early eighties.

THE EIGHTIES, IMPERIAL, CERN AND QUEEN MARY

Imperial College, 1980–1983

In 1980 Ian took over from Paul Matthews as head of the Imperial physics department, while remaining head of the High Energy group. This enabled him to keep abreast of activities in particle physics despite his increasing managerial activities. As department head, he sanctioned an experiment to examine claims by a Stanford team under Blas Cabrera to have observed a signal from a magnetic monopole. An experiment at Imperial was set up, but, like many others seeking to confirm the Cabrera observation, the results were negative.

Ian’s last experiment with bubble chambers had been using neutrinos to probe nuclear structure. In the standard model there are three distinct massless neutrinos distinguished by their flavour, electron type, muon type and tau type. The fact that they are massless prevents transitions from one flavour to another, but as zero mass could not be experimentally demonstrated, massive neutrino theories existed including such transitions, i.e. the phenomenon of neutrino oscillations. At the time, these ideas were considered speculative.

At CERN a second heavy liquid bubble chamber, Gargamelle, was also in use investigating neutrino interactions and where, in 1973, the famous discovery of weak neutral currents had been made. In 1981 Ian was one of nine proponents who submitted a proposal, SPSC P158 (22), to search for neutrino oscillations. The aim was to send a neutrino beam, generated at CERN, first to Gargamelle on the CERN site and then to a detector in the Jura mountains,
Ian Butterworth

17 km away, to see if the flavour composition of the beam had changed. It would have been the world’s first long baseline neutrino experiment and would have had a small, but not negligible, chance of making the major discovery of neutrino oscillation at least 10 years before it was observed in Japan. Regrettably, the perceived wisdom at that time was not that it would reveal startling new physics, but that it would advertise that particles produced at CERN were actually leaving the site. This could have been politically damaging because CERN was keen to construct the LEP (Large Electron Positron) collider, which would involve a tunnel mostly outside the site and needed support from local communities. As a result, the experiment was not sanctioned. Ian was frustrated at the time and even more so when the Nobel Prize winning results from Japan later emerged.

At the beginning of the eighties, construction of the LEP $e^+e^-$ collider became CERN’s major project. This would be much bigger than any previous accelerator, involving a 27 km tunnel so that the electrons and positrons could reach energies to produce the $Z$ bosons responsible for the weak neutral current and to investigate the standard model with far greater accuracy than had previously been possible. Ian strongly supported the LEP project; he was then chair of the Science and Engineering Research Council (SERC) Nuclear Physics Board and he drafted the proposal for UK support for the project, although, as one of the UK delegates to CERN, he had to warn of the limits of UK financial support.

CERN, 1983–1986

In 1983, Ian was invited to become one of the two research directors at CERN and so he resigned his position at Imperial and the family moved to Geneva. His responsibilities included the CERN flagship LEP programme and the CERN computing empire. It was ideal for him. LEP was critical to the future of CERN—and essentially of European particle physics—and the CERN computing division was one of the most advanced and innovative in the world. The latter would strengthen his belief that information technology developments would revolutionize the future, not just for scientific explorations but for life in general. It can be noted that, during his time as research director, he supported a computing group led by Mike Sendall, who was encouraging a revolutionary project by a young computer scientist, Tim Berners-Lee (FRS, 2001). Although Ian left CERN in 1986, he maintained a close interest in the IT activities and he was one of the first to appreciate the great significance the World Wide Web would have for everyone’s future.

Queen Mary, 1986–1990

As much as Ian and his family enjoyed life in Geneva, when invited to become principal of Queen Mary College in London he could not turn it down, and in August 1986 they returned to London. At CERN, he had felt invigorated with the ability to push through ideas and he enjoyed the enterprising atmosphere; however, he found life at Queen Mary different. Changes were much harder to accomplish. Nevertheless, he embarked on a programme to strengthen the College’s standing, partly by promoting external relations with institutions in China and the USA, but more importantly by increasing the College’s influence by mergers. He had two major goals: one was to develop a medical school by a merger with Barts and the London School of Medicine and Dentistry, and the other was to expand the College by a merger with Westfield College. Both were ultimately successful: the latter took 2 years and was finalized in 1989; the former took longer and was not completed until 1995, after he had left his position as principal.
Queen Mary is part of the University of London, so Ian also became involved with the governance of the university. The first appointment was to chair a committee monitoring the University of London Union, but far more significant was his appointment in 1989 as University of London Pro-Vice Chancellor for European Affairs. At the same time he was elected to the recently formed Academia Europaea (AE). He was the ideal person—believing passionately in a pan-European approach for both science and education which could be coordinated at an international level. He actively supported a network of universities in the capitals of Europe; this became UNICA and continues today. Others were less enthusiastic with this global outlook, and he often felt frustrated. He was particularly critical of the UK Institute for Education, which at that time seemed to believe we could learn nothing from our close neighbours.

**Personal**

During the eighties, Ian received many honours. He was elected a Fellow of the Royal Society in 1981 and of the American Physical Society in 1985. In 1984, he was awarded a CBE and in 1987 admitted as a Fellow of Imperial College.

All was progressing well, but then his life changed dramatically in April 1989 when he had a stroke. This caused him to resign as principal of Queen Mary, but, after a remarkably short convalescence period, he was active again and able to pursue his favourite projects.

**POST 1990, BACK TO IMPERIAL — EUROPE, IT AND ELECTRONIC PUBLISHING**

Ian returned to Imperial College in 1990 as a senior research fellow, and continued in this position for the remainder of his life. Ironically, now freed from his responsibilities at Queen Mary, he had the time to pursue a vision for the future based on close European cooperation and the increasing use of IT for research and education, especially in the areas of networking and electronic publishing, ideas that were well ahead of their time. However, first he returned to particle physics research.

**ZEUS**

As his strength improved, Ian decided to take an active part in the group’s research. There were no longer bubble chamber experiments, so he chose to join the group’s activity on the ZEUS experiment, which would soon start data-taking at the HERA (Hadron-Elektron-Ring-Anlage) electron–proton collider at Deutsches Elektronen-Synchrotron (DESY), Hamburg. At that time, the Imperial ZEUS team was stretched in commissioning the detector and so his goal was to boost the physics analysis effort on deep inelastic scattering, as it fitted well with his earlier work with neutrinos. Having no teaching, he was free to make a major contribution to the activities at DESY and, by the time data-taking started in 1992, he was spending considerable time in Hamburg, effectively leading the group’s effort there. He essentially became an active post-doc again, taking shifts and attending meetings of the running and analysis groups and doing any jobs on the experiment which needed doing. He found it enjoyable and recuperative.

To catch up with the latest advances, he gave a lecture course to the postgraduates on deep inelastic scattering and became an effective supervisor for a number of them. The much higher energy at HERA gave greater penetrating power to investigate nucleon structure, and
important and unexpected results were obtained, probably the most significant being the rise
of the gluon structure function $F_2$ at low Feynman $x$, i.e. in the core of the proton. With one
of the students, Alex Prinias, he produced analyses on this in 1995 and 1996 (24, 25).

By 1994 the Imperial team had been significantly strengthened, with two younger staff
members, and at the same time pressures arising from his European activities were becoming
greater, so Ian started to phase out of ZEUS and by 1996 he had effectively left the experiment.
He did, though, continue to play an active role in the High Energy group and became de facto
head again, although technically deputy, when the author was on leave of absence in CERN
from 1997 to 2000.

**Other activities—IT, Europe and many committees**

Ian was an international person: he enjoyed different cultures and examining the differences
with the UK, both better and worse. During his early career this was centred on the US, then the
powerhouse for the emerging activity in particle physics, but during the 1980s Europe, through
CERN, began to take the lead in the particle physics world and when appointed Research
Director at CERN in 1983 he realized a strong affection for things European. He saw the
great merits of pan-European solutions for science and education, particularly by exploiting
information technology.

Ian was never a software expert—it is unclear whether he ever wrote a line of code—
however, he passionately believed that IT would be critical for future developments and
must be embraced. His interests evolved when research director at CERN, where the ideas
of networking, the Internet and ultimately the World Wide Web had been advancing rapidly.
Although these had been originally designed for particle physics, where data rates were
high and collaborating institutes spread worldwide, Ian had the vision to appreciate the huge
potentialities in many other areas.

**Electronic publishing, the IoP and IUPAP**

Ian started putting these ideas into practice when, in 1993, he was appointed vice president
of the Institute of Physics (IoP), with responsibility for publications, and chair of the board at
IoP Publishing (IOPP). This enabled him to advance the cause of electronic publishing despite
objections by many in the publishing area. It became a cause célèbre, and in 1994 he was justly
proud when the world’s first-ever electronic journal in physics, *Classic and Quantum Gravity*,
was published by the IOPP. By early 1996, all the IoP journals were on the Web, again a first
for a major publisher, and it prompted others, such as the American Physical Society (APS),
to follow suit. It marked a revolution in scientific publishing, for which he can take much
credit. In 1997, he organized a workshop on this subject and a summary of the proceedings
was published; it is one of the first systematic contributions in this area (26).

In 1998 the International Union of Pure and Applied Physics (IUPAP) formed a group, with
Marty Blume from the APS as chair and Ian as secretary, to advance the case for electronic
communications to a wider public. It led to a major IUPAP document in 2001 (29).

**The Academia Europaea**

Ian’s contributions to the AE workshops were formally recognized when he was appointed
vice president in 1997, and thus a spokes person for European activities in the general science
area. It was a position he relished as he could influence policy on information technology
for advancement of learning and research across Europe. As a passionate advocate of the
benefits of increased European cooperation, he was often at odds with other advisors to the UK government, who could display a distinct anti-European sentiment. One merciful thing was that he did not live to see the Brexit vote.

By 1998 the impact of the World Wide Web and all forms of electronic communication were becoming much more widely appreciated. To take note of this, the European Commission asked the AE to organize the Euroscientia conference on Electronic Communication and Research in Europe; this took place in Darmstadt in April 1998 with Ian co-chairing the organizing committee (27). The Commission also formed ETAN (European Technology Assessment Network), a wide-ranging study of the changing situation including an expert working group ‘Transforming European science through information and communication technologies: challenges and opportunities of the digital age’, which Ian chaired (28).

By the end of the nineties, Ian’s interests had broadened to general computer networking for the European academic community. With Enric Banda, then secretary general of the European Science Foundation (ESF), he organized a HIBEER (High Bandwidth for European Education and Research) workshop, resulting in pressure on European authorities to move quickly to implement the GÉANT network. As networking became a major issue, the eEurope initiative for a formal pan-European network infrastructure was proposed by the Commission and endorsed at the Lisbon European Union summit in 2000 and, following the HIBEER workshop, Ian was instrumental in establishing SERENATE (Study into European Research and Education Networking as Targeted by eEurope). A final report (30) for the European Commission was produced in December 2003 on the status of networking, with both suggestions for future aims and warnings of potential future problems.

As vice president of the AE, he took an interest in the state of research infrastructures all over Europe, including the poorer areas in south-east Europe where the research infrastructure was virtually non-existent. As a consequence, at a UNESCO Ministers of Science meeting in October 2001, he urged the formation of a regional network for south-east Europe, to be collaboratively owned by the various countries. This came into being as SEEREN (South-Eastern European Research & Educational Networking) in January 2004, joining the national networks in the various countries and eventually connecting with the main GÉANT development.

Ian’s time as vice president of the AE terminated in 2003, but he continued to support the organization until retiring from the Physics and Engineering Sciences Committee in 2008.

**PESC and ESF**

In parallel with his AE activities, additional involvement with European affairs came when he replaced Ian Halliday as the Particle Physics and Astronomy Research Council (PPARC) representative on the Physical and Engineering Science Committee (PESC) of the ESF in 2000, becoming a member of the PESC Core group from the start of 2001. Within PESC he would now influence European activities in many areas of physics, although, again, his primary goal was to push or cajole different bodies to embrace the potentialities offered by IT advances.

During this period, there was much discussion concerning the need or advisability of a European Research Council (ERC). Views varied widely in the member states, but PESC was in the forefront promoting the ERC. Discussions continued over a number of years, but eventually it was approved by the Commission in 2005 and finally set up in 2007. It thrives to this day and is considered a fine example of European cooperation.
In the years following his stroke, the desire to see the benefits from the Internet and European cooperation materialize drove him almost without rest. This had to be achieved through organizations and committees, which were often frustratingly slow and indecisive, but a necessity to achieve the goals. Ian was in fact a superb committee person, invariably well briefed before meetings and with a well thought out agenda. He would always listen to technical experts and seriously consider the opportunities they suggested; however, he was far less prepared to take account of bureaucrats who could find difficulties for political aims.

**Final years**

By 2006 Ian started to cut down his heavy schedule and slowly relinquish his positions on these committees. This became even more necessary as, towards the end of 2006, Mary became seriously ill and effectively bedridden. Ian, Mary and their daughter, Jody, had always been a tight-knit family and so now caring for Mary took priority for Ian and Jody. Mary eventually died in April 2007. Jody had provided great support for Ian during this difficult period and this continued for the remainder of his life.

For these final years, the release from so many committees enabled him to fully indulge his non-scientific interests, specifically fine art, literature, fine food and fine wine. He and Jody became regular attenders at lectures in London, invariably to be followed with a good meal. These pleasures were not limited to London; he never lost his affection for the continental life and so he would often take the opportunity to visit France or Italy, with the aims again being dominated by art and gastronomy. Although Mary’s death was a great loss, these final years became a contented period; Jody was an enjoyable and supportive companion, and the two became a close three when Jody became engaged to Nicholas. Ian would see them happily married in 2012.

He passed his eightieth birthday in fine spirits in December 2010 and thoroughly enjoyed a dinner to celebrate this at Sally Clarke’s Kensington restaurant in January 2011 (Figure 1).
Biographical Memoirs

His health, however, began to fail later in 2011, possibly brought on at least partially by a bizarre accident at the V&A museum, when he was actually knocked over and broke his wrist. This healed, but he was never quite the same, although he did manage the Imperial High Energy group Christmas party in 2011. During 2012 he had a number of operations followed by lengthy periods of recuperation which he found frustrating. In June 2013, he had a small heart attack, which led to another operation and unfortunately an infection. He died at home on 29 November 2013.

Biographical summary

Career

1951 BSc Manchester University
1954 PhD Manchester University
1954–1958 Senior Scientific Officer, Atomic Energy Authority
1958–1964 Lecturer, Physics Department, Imperial College
1964–1965 Physicist, Lawrence Radiation Laboratory, Berkeley, California
1965–1968 Senior Lecturer, Imperial College
1968–1971 Head of Bubble Chamber Group, Rutherford Laboratory
1971–1983 Professor of Physics, Imperial College
1971–1983 Head of High Energy Physics, Imperial College
1980–1983 Head of Department of Physics, Imperial College
1983–1986 Research Director, CERN
1986–1991 Principal, Queen Mary and Westfield College
1989–1991 Pro-Vice Chancellor for European Affairs, University of London
1991–2013 Senior Research Fellow, Imperial College

Honours and medals

1981 Fellow of the Royal Society
1984 Commander of the British Empire
1986 Fellow of the American Physical Society
1987 Honorary Member, Manchester Literary and Philosophical Society
1988 Fellow of Imperial College
1989 Elected to Academia Europaea
1993 Glazebrook Prize and Medal, Institute of Physics

Learned society activity

1997–2003 Vice President, Academia Europaea
1997–2003 Chair, Programme Sub-Committee of Academia Europaea
1998–2006 Secretary, Advisory Committee on Communications, IUPAP
2000–2006 IUPAP Representative on ICSTI Executive Board

Major committees

1972–1975 Chair, Film Analysis Grants Committee, SRC
1972–1975 Nuclear Physics Board, SERC
Ian Butterworth

1979–1983 Chair, Nuclear Physics Board, SERC
1979–1983 SERC Council
1979–1983 UK Delegate on CERN Council
1976–1982 CERN Research Board
1976–1982 Chair, CERN SPS Committee
1981–1985 Research Council, DESY, Hamburg
1983–1986 CERN Research Board
1984–1988 Scientific Policy Committee, SLAC, California
1989–1990 Council, Royal Society
1993–1997 Vice President, Institute of Physics
1999 Chair ETAN Export Working Group on ‘Transforming European Science through ICT’, DG for Research
2000–2003 UK UNESCO Science Sector Committee
2000–2006 UK Representative, Core Committee, Physical Sciences & Engineering Standing, European Science Foundation
2004–2006 UK UNESCO Natural Sciences Committee

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AUTHOR PROFILE

Peter Dornan

I met Ian Butterworth when I joined Imperial College as a post-doc in 1967 and, when he moved to the Rutherford in 1968, he left an academic vacancy to which I was appointed. Our close relationship started in earnest when he returned to Imperial as head of the group in 1971. During his absence, I had been working on the commissioning of the automatic Hough–Powell measuring machine, one of his pet projects, and the relationship was cemented when, together, we established the group’s involvement with the SLAC Hybrid Facility in Stanford in 1973. Our scientific paths diverged as the eighties approached, I moved to colliding beams and Ian to neutrino physics, but by this time we had developed a bond of friendship and trust which continued for the remainder of his time. In 1992, I became head of the High Energy group and, when I took leave of absence to be at CERN from 1997 to 2000, Ian became my deputy, so we stayed in close contact over the health of the group. After my return, our contacts were mainly social, often enjoying a fine dinner together. One of the last things I was to do...
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for him was to organize an eightieth birthday dinner at Sally Clarke’s in Kensington—it was a happy occasion.

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(9) 1970 (With A. Berthon, L. K. Rangan, J. Vrana, P. J. Litchfield et al.) The reaction $K^-p\rightarrow\Lambda\pi^0$ in the centre-of-mass energy range 1915 to 2168 MeV. Nucl. Phys. B 20, 476–492. (doi:10.1016/0550-3213(70)90383-4)


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